XLIII.—*On the Spiral Growth of Appendages in Course of Regeneration in Arthropoda.* By Edmond Bordage *.

I.—In a previous communication to the Academy I noted the spiral manner of growth of limbs in process of regeneration among the Mantidæ. I recalled the fact that this special mode of growth is common to the Phasmidæ and to the Blattidæ †. I should add that this peculiarity ought probably to be met with in the four classes of Arthropoda and in the case of different appendages ‡. So far as insects are concerned, the fact is now proved as regards the limbs. Furthermore, I have been able to convince myself that after amputation the antennæ of the larvæ of Phasmidæ (*Monandroptera* and *Raphiderus*) grow in a spiral until the first moult which follows the mutilation.

Among the Crustacea spiral growth has been determined in *Cancer pagurus*, *Carcinus mœnas*, and *Pagurus Bernhardus* by H. Goodsir ('Anatomical and Pathological Observations,' Edinburgh, 1845).

Among the Arachnida the Araneidea show it clearly.

In Myriopoda it has not yet been noted. It seems probable, however, from what few researches have been made upon regeneration of limbs among these Arthropoda. It should most probably be seen at least in Myriopods with well-developed limbs, such as the Scutigeræ (*Scutigera*). The latter present a remarkable peculiarity. Before they have attained their full development there can be made out rolled up under the skin, owing to its transparency in the terminal segment of the body, a number of limbs—limbs which do not become free and rectilinear until the following moult. After each moult the body of *Scutigera* gains an additional segment.

II.—I ought, however, to mention that spiral growth is not met with in all Arthropoda. In the lobster, for instance, the thoracic limbs when in process of regeneration grow in a rectilinear manner. This fact is the more remarkable inasmuch

* Translated from 'Comptes Rendus,' cxxix. (1899) pp. 455–457, by Wilfred Mark Webb, F.L.S. From a separate impression communicated by the Author.

† I have just discovered that Mr. H. Brindley had noted this manner of growth in the Blattidæ (Brindley, 'On certain Characters of Reproduced Appendages in Arthropoda,' p. 9, 1898).

‡ Researches, experimental as well as bibliographical, have, however, shown me that this mode of growth is not met with in all the Arthropods, as one would have been at first inclined to suppose.

as the mutilated antennæ of the same crustacean grow in a spiral until the first moult after the injury.

The difference between the two modes of growth is not so great as at first might be imagined. Let us see in what it consists. In Arthropods showing spiral growth, as in those which present the rectilinear method, the surface along which the separation is made between two successive joints of a limb becomes covered by a thin non-chitinous cuticle. In one case as in the other the work of regeneration begins not over the whole surface of the cut, but near the central part, and growth is generally much more rapid in length than in diameter, with the result that the rudiment of the limb in course of development has at first a diameter greatly inferior to that of the stump remaining in place.

If growth proceeds rapidly, as is most usual, and if no turgidity of the limb-rudiment shows itself, the latter, by reason of its flaccidity, is incapable of pressing with any force against the thin cuticle covering over the cut surface. It is only able to distend it slightly in order to obtain necessary room for itself. Under these circumstances it is obliged to coil upon itself while remaining covered by the cuticle, which forms a kind of protecting sheath.

If, however, on the contrary, turgidity shows itself from the beginning of growth, the rudiment of the limb in process of formation, instead of being obliged to coil itself, is able to push before it the thin cuticle endowed with very considerable elasticity. In this case nothing hinders rectilinear growth. The cuticle in question can even mould itself in a more or less perfect way upon the growing limb, and remains until the time of the next moult. It is then cast off with the old chitinous covering of the body, with which it is intimately connected.

To epitomize the question, the development of the limb will follow the spiral or the rectilinear form, according as there is flaccidity or turgidity of the rudiment of the limb being replaced at the beginning of its formation.

III.—So far as insects are concerned [Mantidæ, Blattidæ*, and Orthoptera saltatoria], regeneration of a part of the limb after *artificial severance* most often takes place by means of the spiral manner of growth. I have nevertheless found some exceptions which can be explained easily enough also and considered as a particular case of the more usual process. Thus, among the Phasmidæ, whilst a limb amputated by self-mutilation regenerates itself according to the method involving spiral growth, the regeneration of part of a limb

* *Cf.* H. H. Brindley, 'On certain Characters of Reproduced Appendages in Arthropoda,' p. 9 (1898).

removed by an artificial cut, on the other hand, follows the method of rectilinear growth [see Bordage, "Régénération des membres chez les Phasmides après des sections artificielles" (Ann. Soc. Entom. de France, p. 87, 1898)].

In the paper referred to, after having indicated that the growth of self-mutilated limbs in course of replacement takes place with relatively remarkable speed, I added that, on the contrary, in the case of parts of limbs artificially removed by cutting it proceeds with the greatest slowness. The part, however, in course of regeneration after artificial severance having of necessity immediately after the next moult the same diameter as the termination of the stump of greater or less length remaining in place, it follows that growth in diameter must be quite as rapid as in the Mantidæ and Blattidæ. It is even sometimes as rapid as the growth in length * and that exactly at the commencement of the regenerative process, but at this period alone. Afterwards it slackens considerably and follows the speed of growth in diameter of the whole limb with which it is to be blended.

In this way the work of regeneration of a part of a limb which has started, as is the rule, near the central portion of the cut has already spread to the whole surface of the latter before the rudiment of the limb has attained an appreciable length. This rudiment possesses then the diameter of the part of which it is a prolongation, and its insignificant length does not compel it to coil upon itself under the protecting cuticle, as would certainly happen if its growth in length were rapid and if its diameter remained at the same time much smaller than that of the stump which it must complete. It can then stretch the thin cuticle before it during its whole extension and grow rectilinearly.

I have been able to determine that the same thing happens sometimes in Orthoptera saltatoria following artificial division carried out on the two front pairs of limbs either on the lower part of the tibia or on the first joints of the tarsus in the jumping-legs. Here, however, this result is not constant, as in the Phasmidæ. It only follows in the case where, from some cause or other, regeneration takes place with great slowness. Otherwise the growth is spiral.

We have, then, a second cause leading to the rectilinear growth of a member in course of regeneration. It is proper to add that in this case turgidity seems also to play a certain part.

* Thus I have determined that in a larva of *Monandroptera inuncans*, after the moult, which occurred in the first place some time after the artificial severance of a limb 2 millim. in diameter at the point where section had been performed, the terminal projection formed by the part in course of regeneration had itself scarcely reached 2 millim. in length.